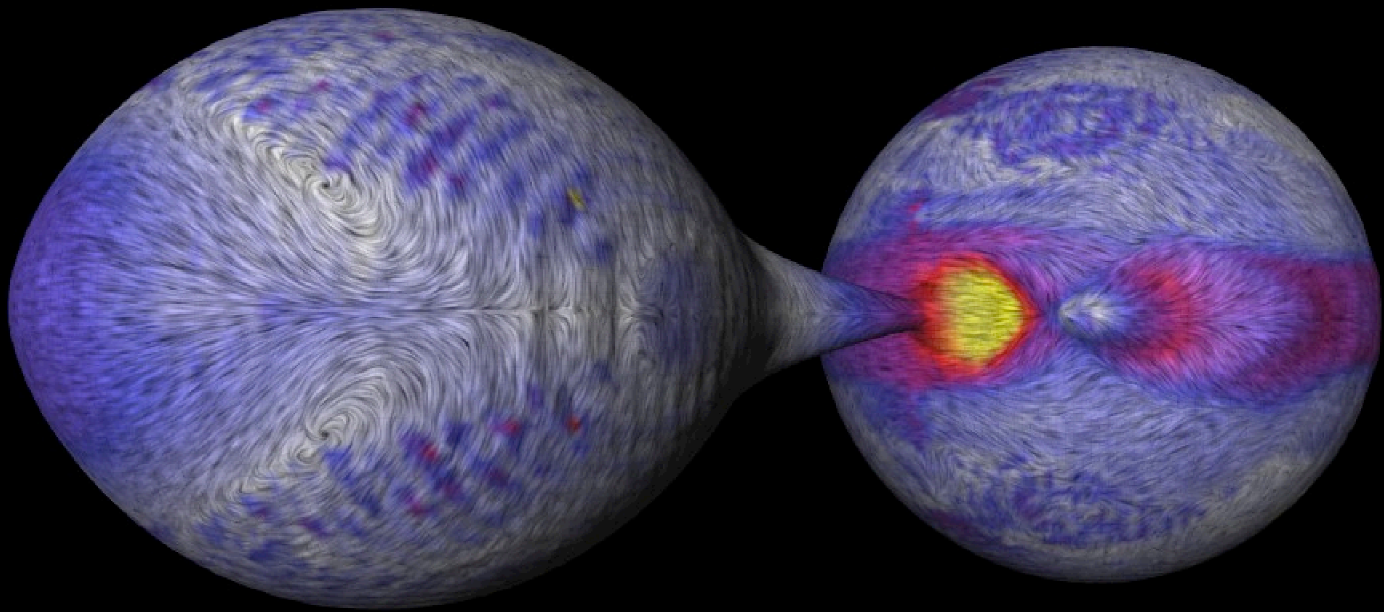
Angular Momentum Transport in Double White Dwarf Binaries



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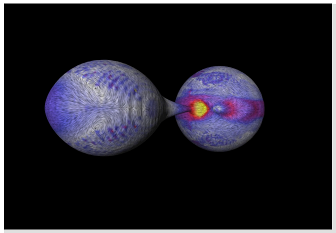
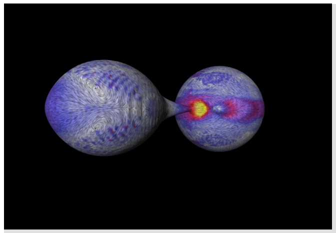
Sixth International LISA Symposium June 22, 2006



Outline

- Introduction of Double White Dwarf (DWD) Binaries and motivation for the simulations
- Simulation of a DWD binary with $q = 0.4$ initially
- What did we see? Interpretation through the orbit averaged equations
- Measuring the effective mass ratio for stability to mass transfer
- Conclusion

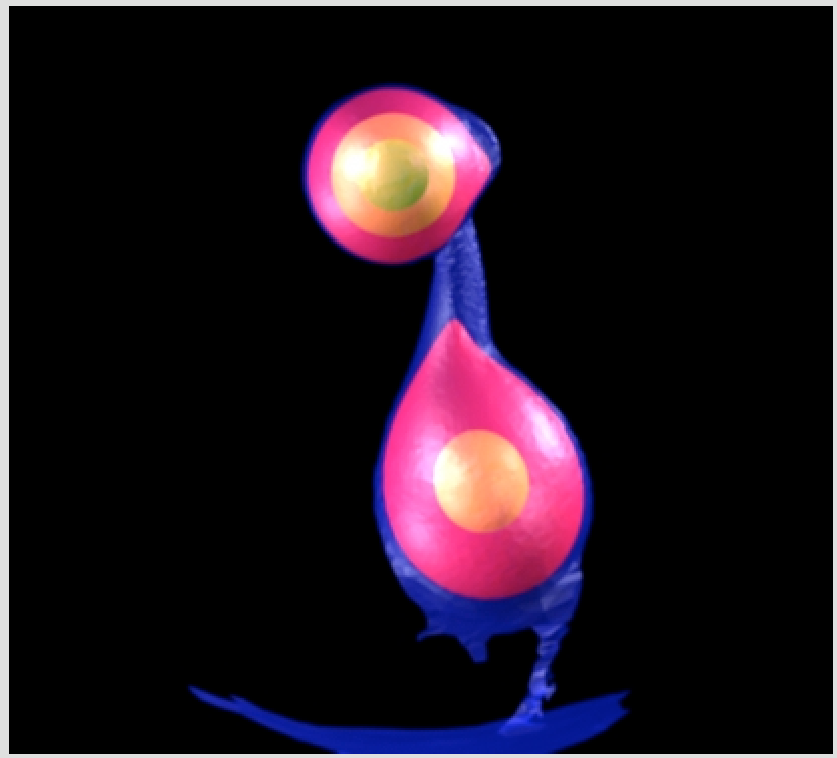


Introduction to Double White Dwarf Binaries

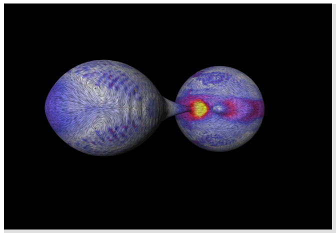
Radius proportional to mass $^{-1/3}$ The least massive star reaches contact first and will expand on mass loss.

If orbital angular momentum is conserved, expect mass transfer to be stable if the mass ratio, q, <= 2/3

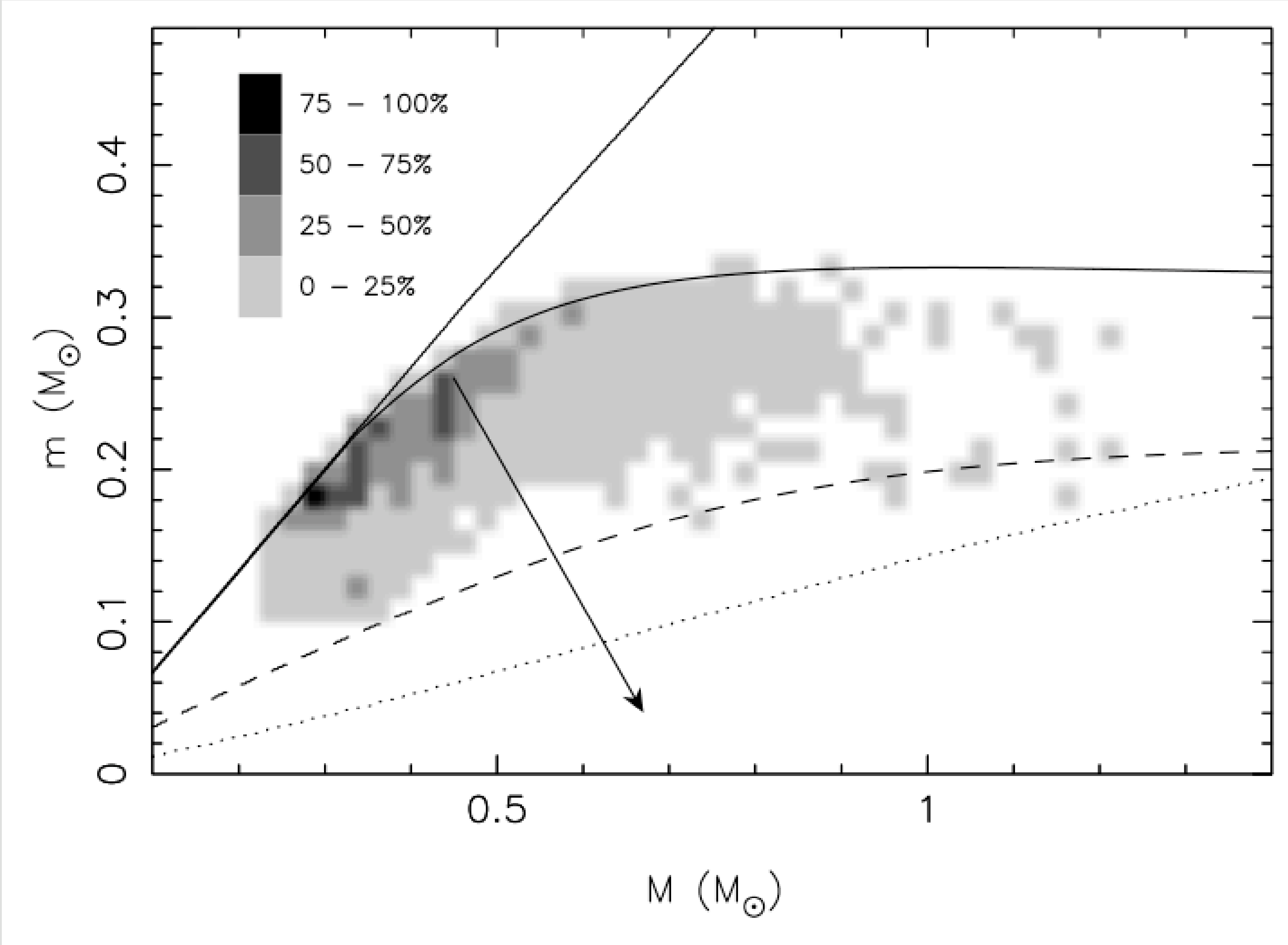
In many instances, the accretion stream can not form a disk about the accreting WD. Instead it strikes the star and spins it up at the expense of the orbital angular momentum of the binary.



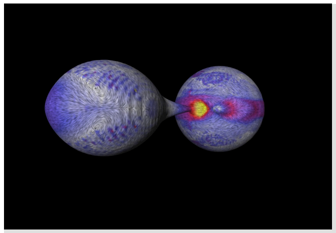
D'Souza *et al*. (2006)



Introduction to Double White Dwarf Binaries

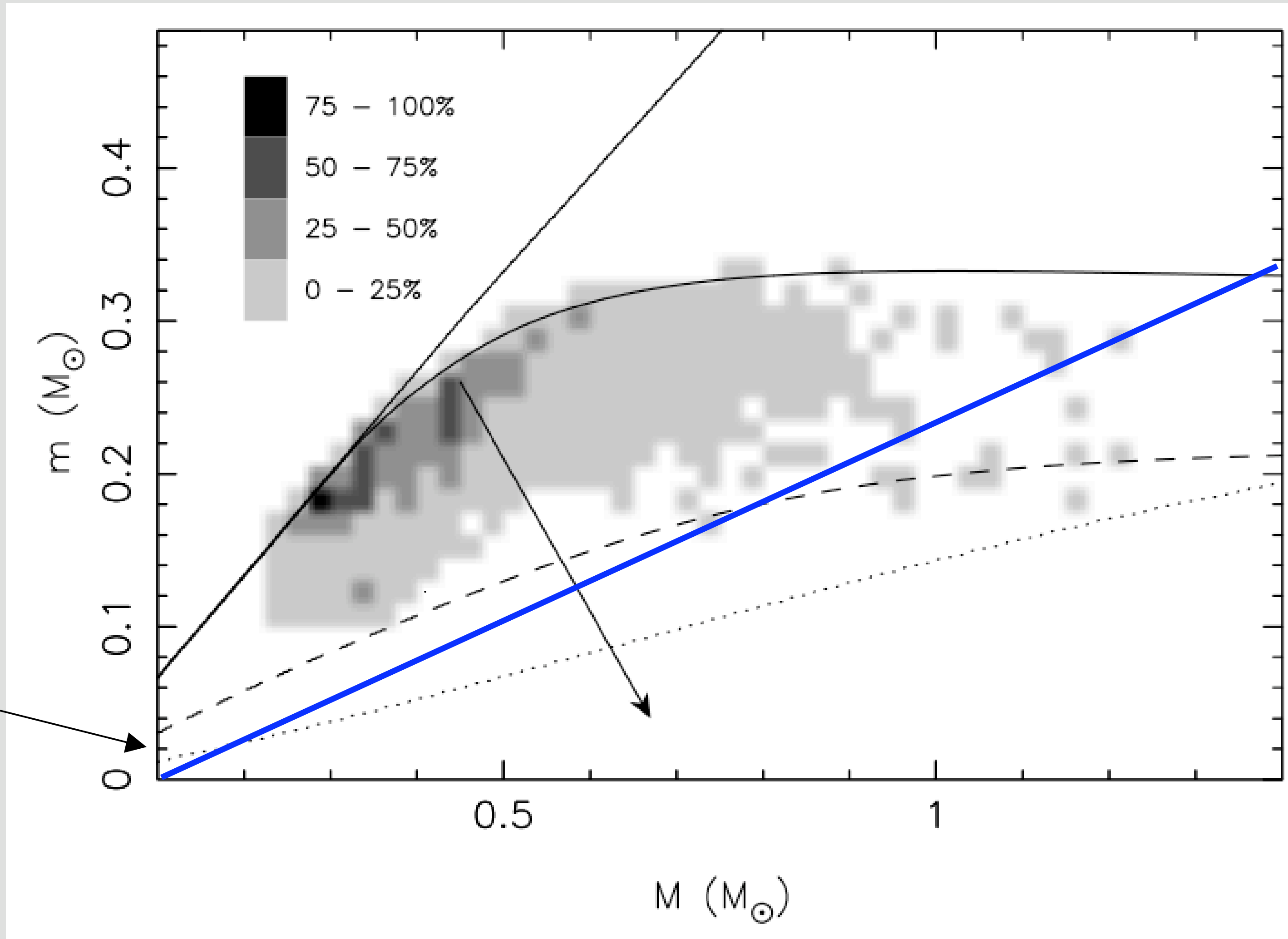


From Nelemans *et al*. 2001, A&A, **368**, p939



Introduction to Double White Dwarf Binaries

q = 0.4



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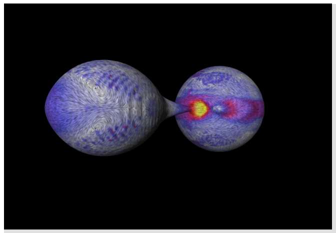
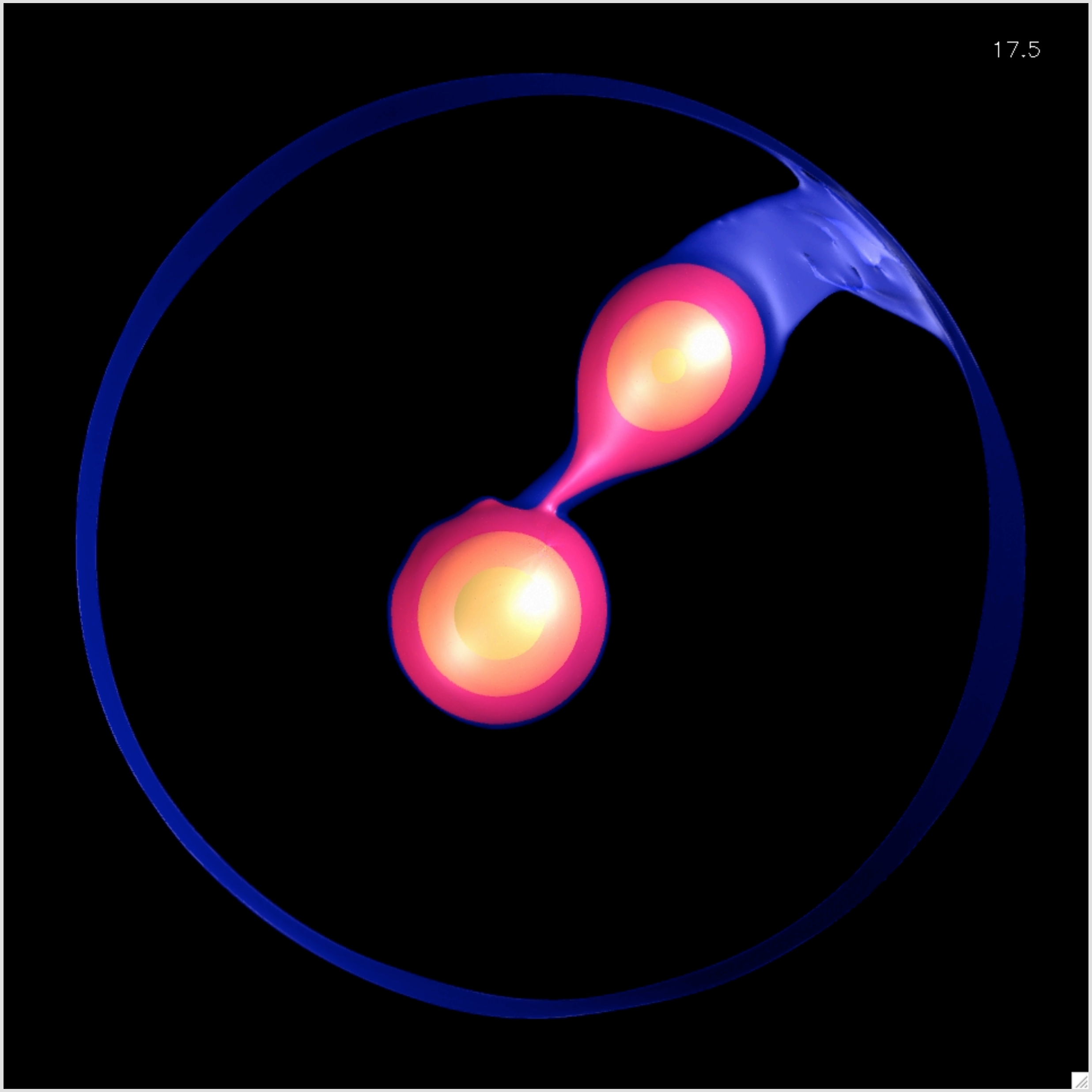
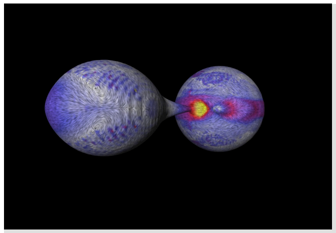


Evolution of q = 0.4 binary





What happened?

Analyze the simulation in terms of a simpler description. Begin with the decomposition of angular momentum as

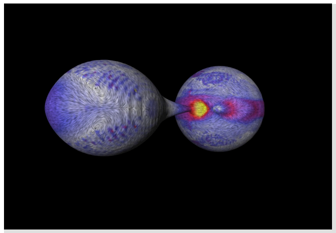
$$J = J_{\rm orb} + J_A + J_D$$

Combine this with the expression for orbital angular momentum for a point mass binary

$$J_{\rm orb} = M_A M_D \sqrt{\frac{Ga}{M_A + M_D}}$$

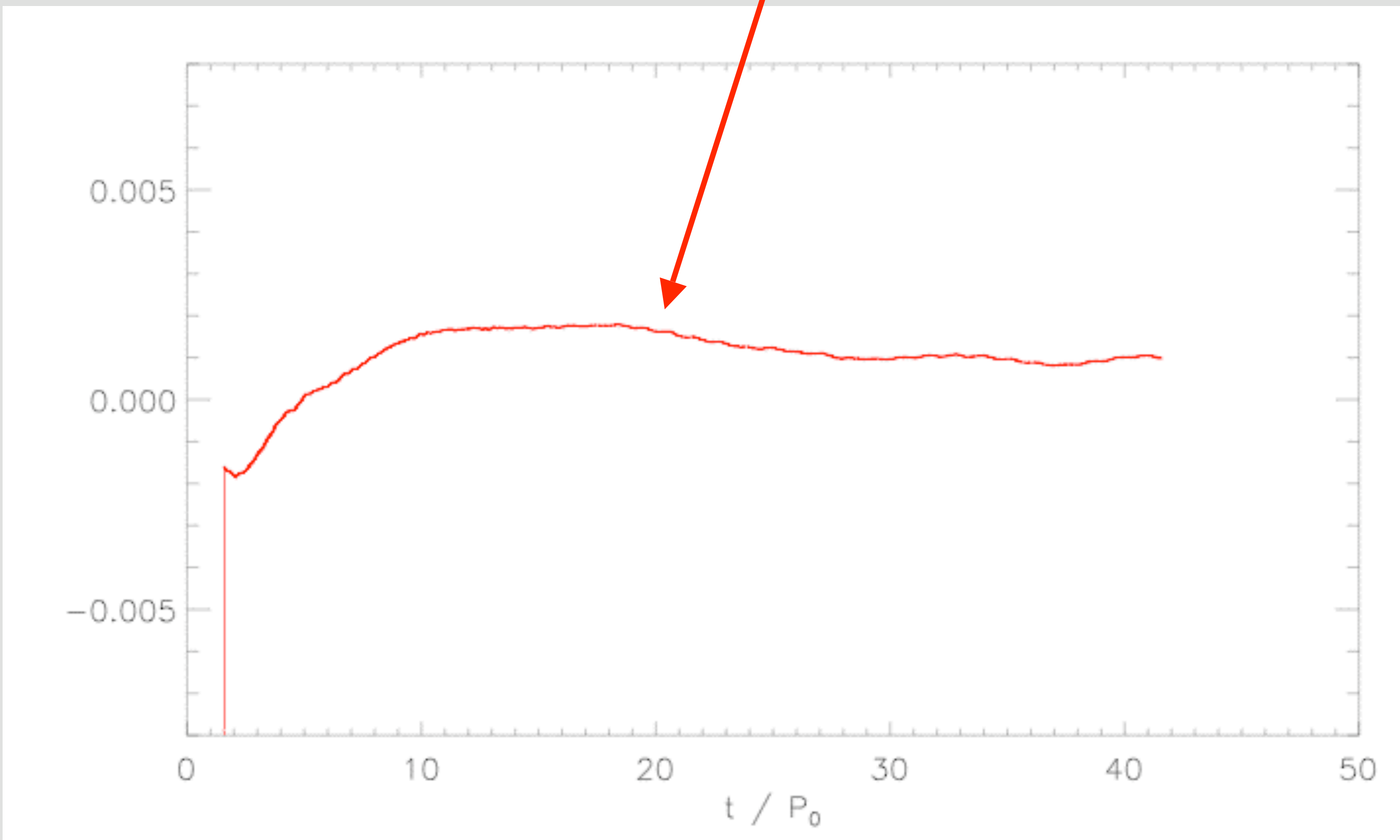
To obtain

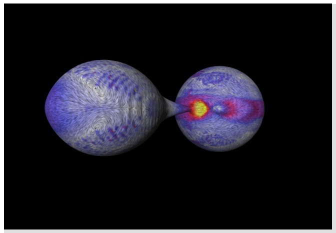
$$\frac{\dot{a}}{2a} = \left(\frac{\dot{J}}{J_{orb}}\right)_{driving} - \frac{\dot{J}_A}{J_{orb}} - \frac{\dot{J}_D}{J_{orb}} - \frac{\dot{M}_D}{M_D}(1-q)$$



Right Hand Side

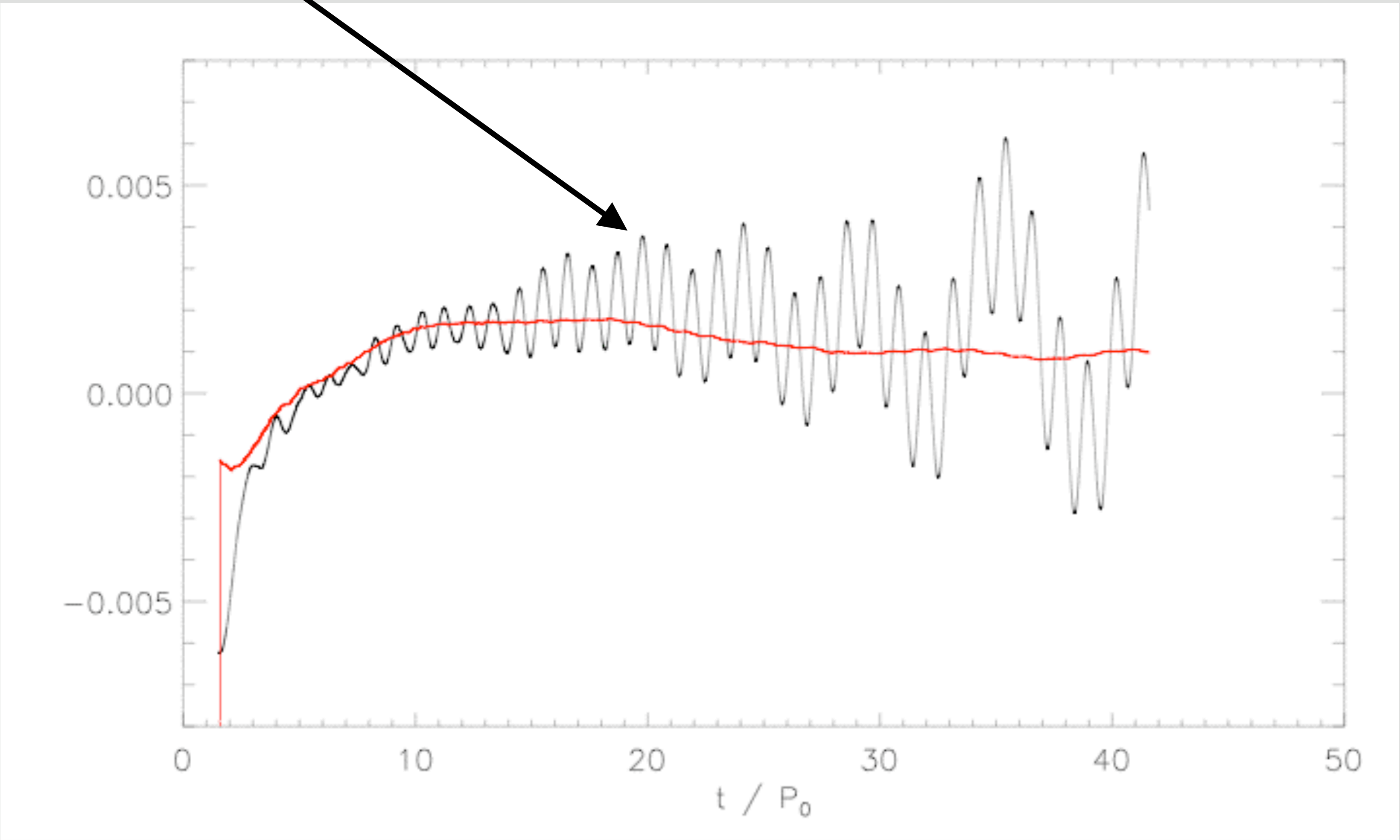
$$\frac{\dot{a}}{2a} = \cancel{\left(\frac{\dot{J}}{J_{orb}}\right)}_{driving} \underbrace{- \frac{\dot{J}_A}{J_{orb}} - \frac{\dot{J}_D}{J_{orb}} - \frac{\dot{M}_D}{M_D}(1-q)}$$

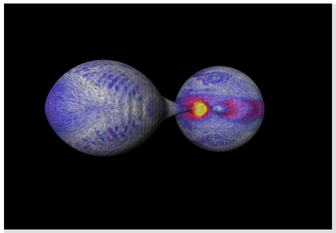




Left Hand Side

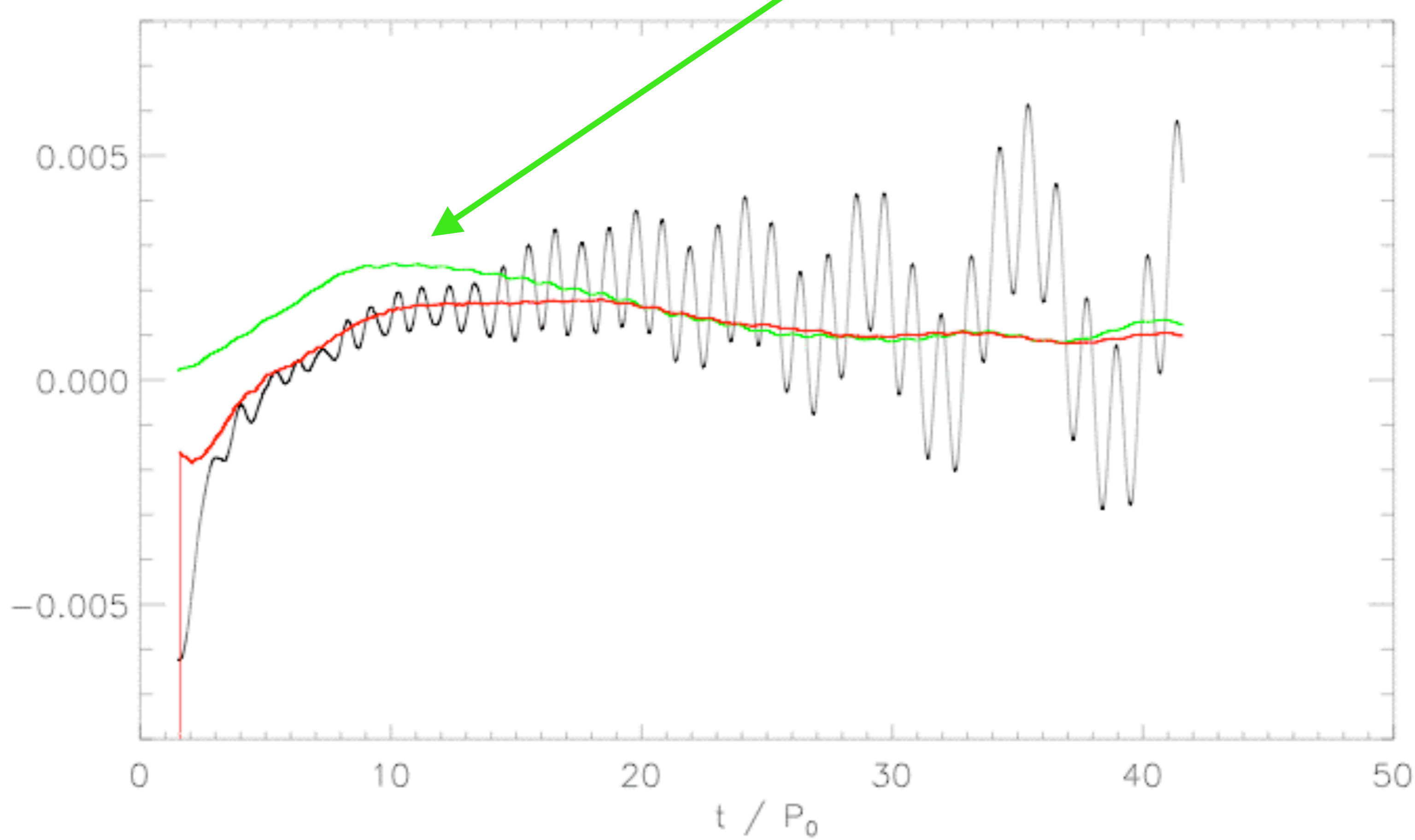
$$\frac{\dot{a}}{2a} = -\frac{\dot{J}_A}{J_{orb}} - \frac{\dot{J}_D}{J_{orb}} - \frac{\dot{M}_D}{M_D}(1-q)$$

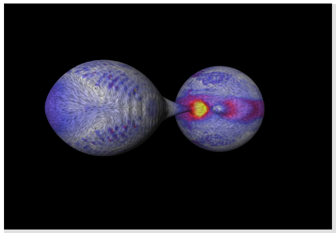




Mass Transfer Term

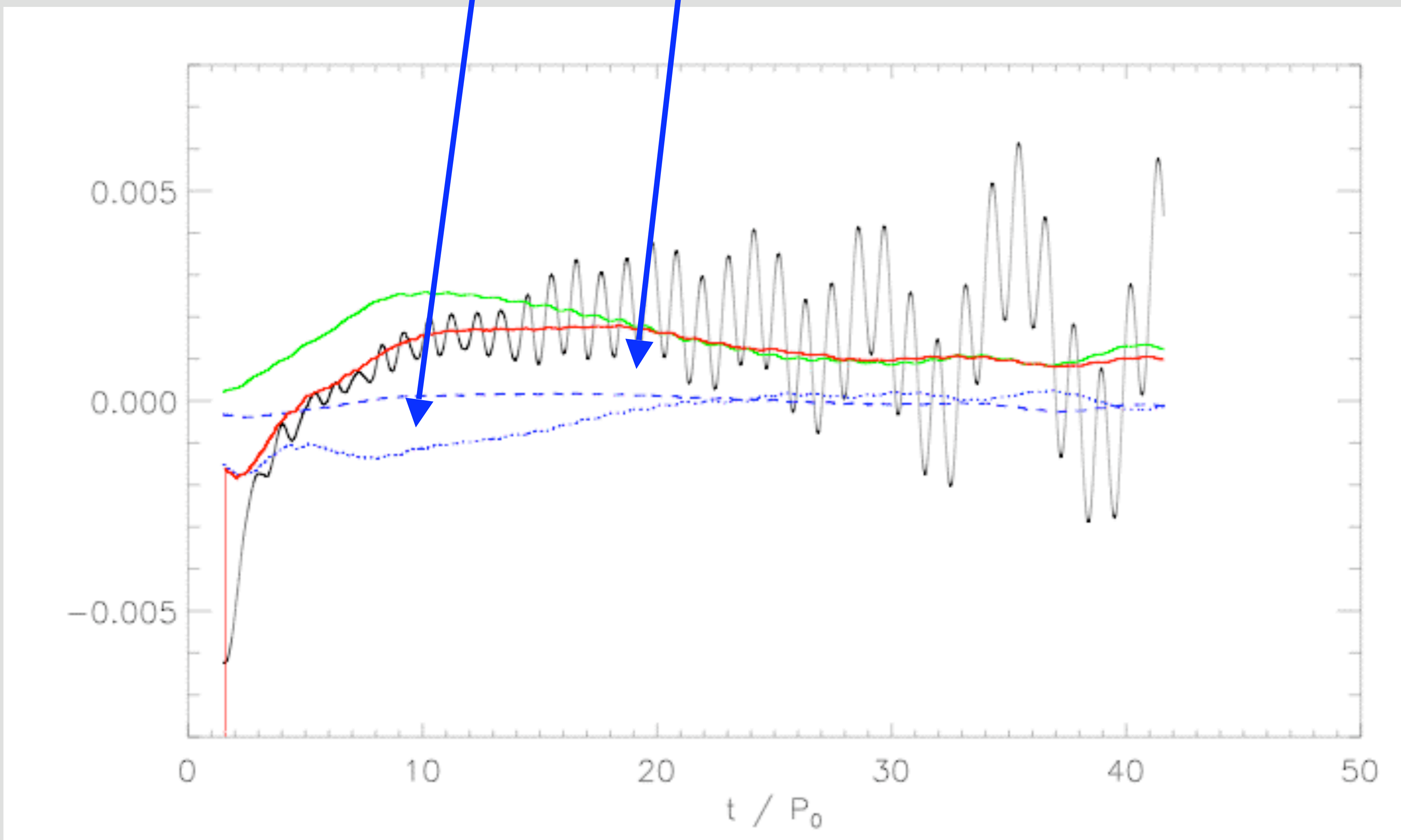
$$\frac{\dot{a}}{2a} = -\frac{\dot{J}_A}{J_{orb}} - \frac{\dot{J}_D}{J_{orb}} - \frac{\dot{M}_D}{M_D}(1-q)$$

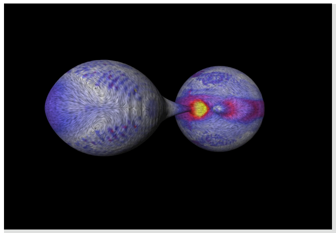




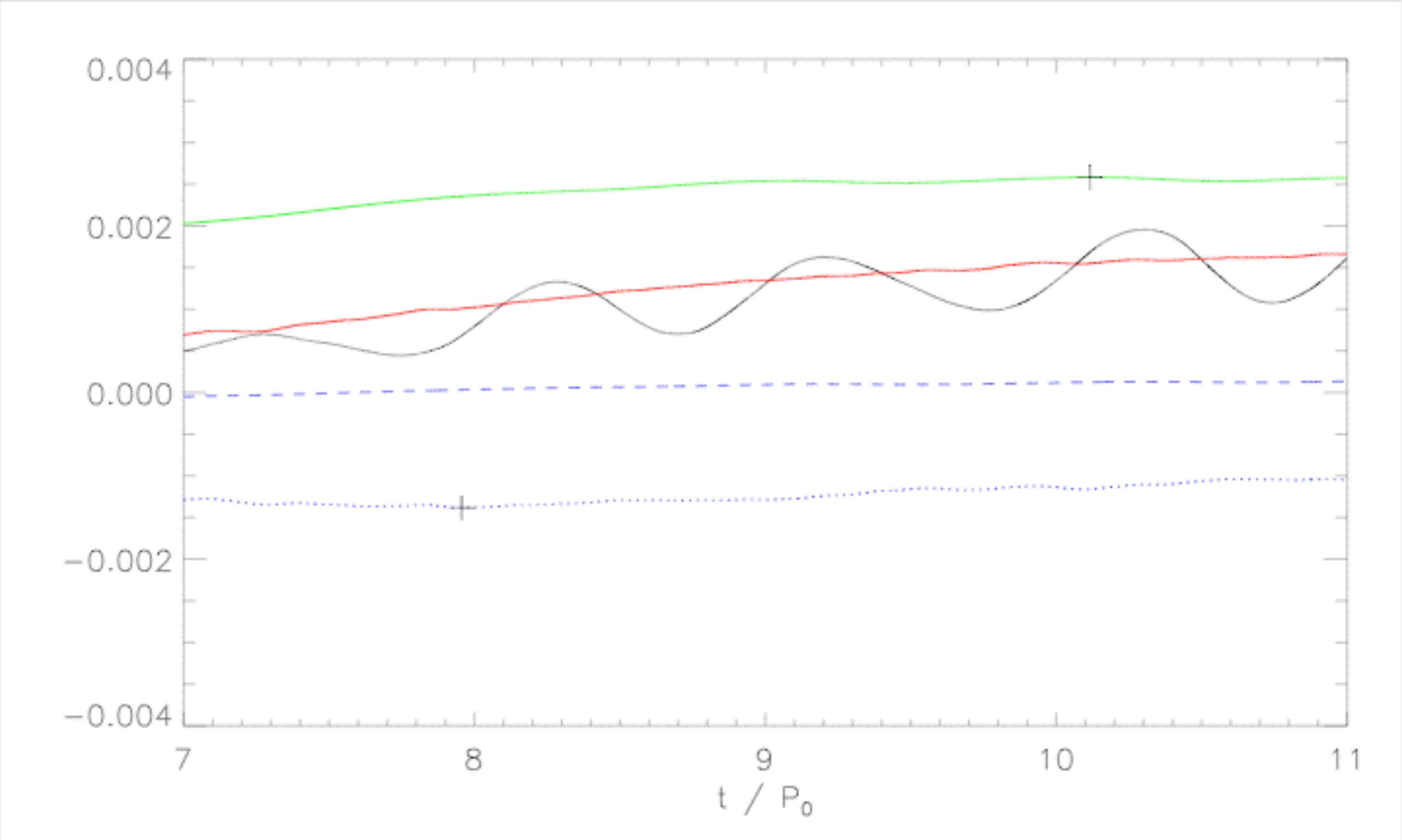
Spin Terms

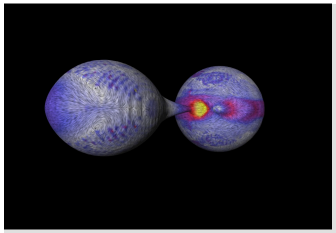
$$\frac{\dot{a}}{2a} = -\frac{\dot{J}_A}{J_{orb}} - \frac{\dot{J}_D}{J_{orb}} - \frac{\dot{M}_D}{M_D}(1-q)$$





Closeup view of a subtle point



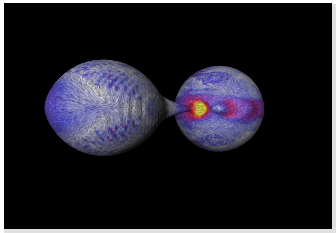


Measuring the Critical Mass Ratio

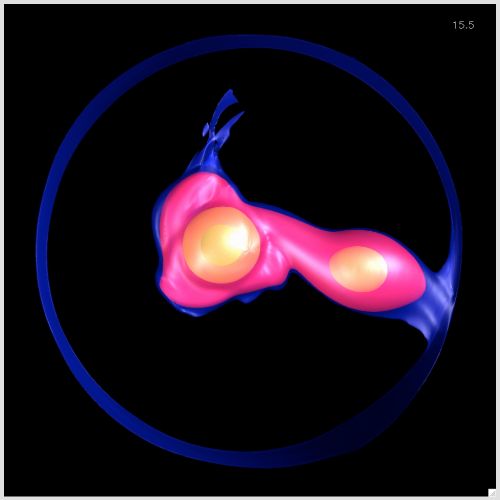
Impose a sink for angular momentum to drive the binary during the simulation.
We can then, in principle, force the system to its equilibrium mass transfer rate

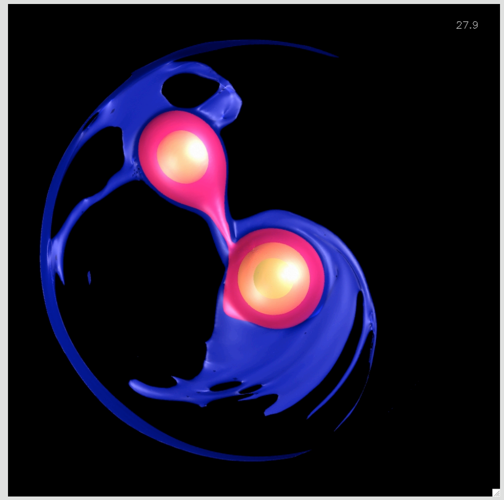
$$\dot{M}_{\mathrm{equilibrium}} = M_D \frac{\left(\frac{\dot{J}}{J}\right)_{\mathrm{driving}}}{(q_{\mathrm{crit}} - q)}$$

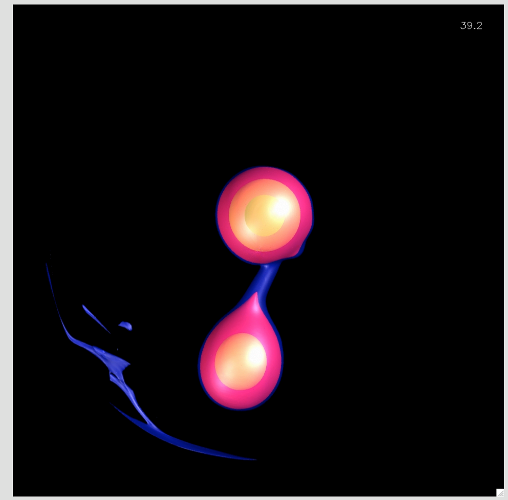
And then measure the effective mass ratio for stable mass transfer, q_{crit} . We ran evolutions with driving rates of 5 x 10^{-3}, 2 x 10^{-3} and 1 x 10^{-3}.

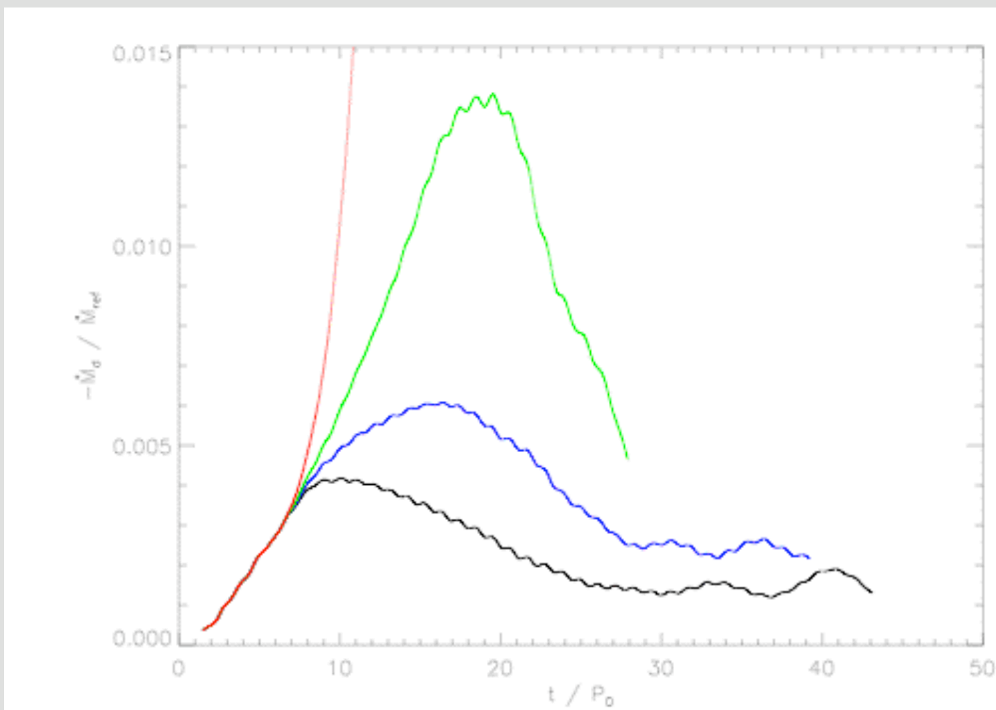


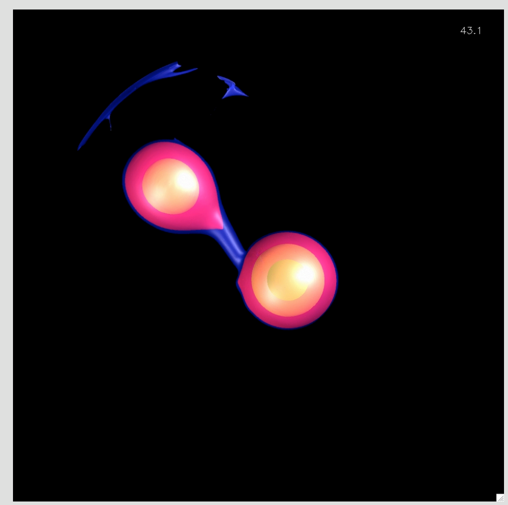
Driven Evolutions

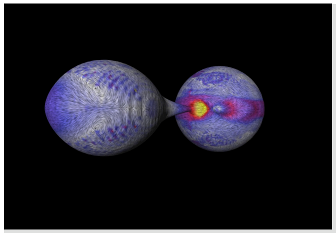






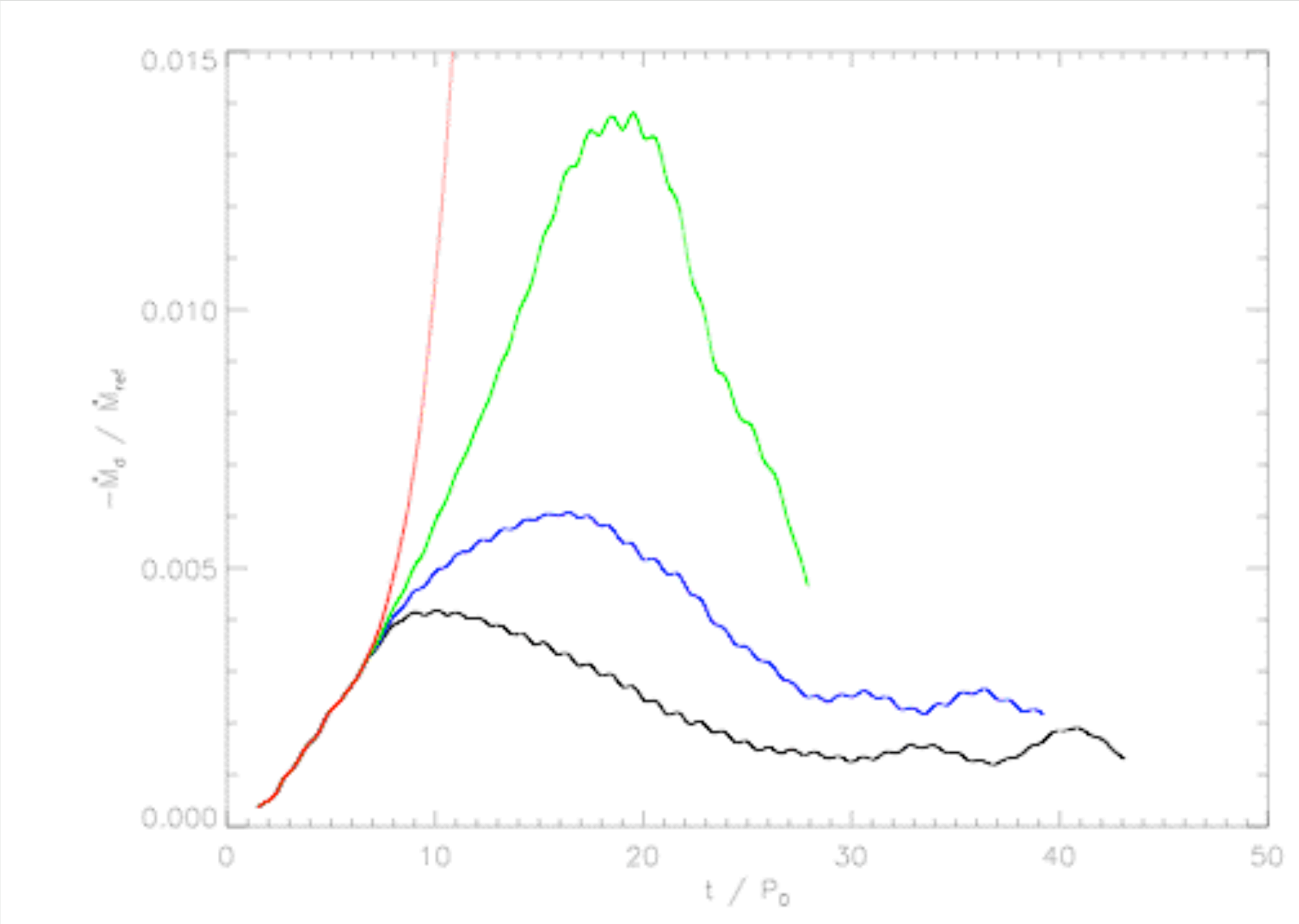


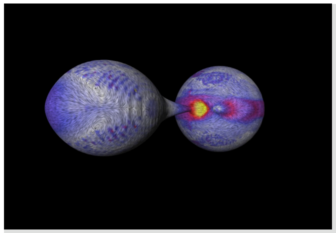




Effective q_{crit}

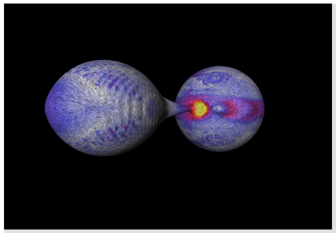
Using the nearly steady state mass transfer rate and the imposed driving rate, we deduce $q_{crit} \sim 0.7$





Conclusions

- Even in the case of direct impact accretion, a DWD that is initially unstable can survive
- This view is bolstered by the evolution of a DWD binary with q = 0.5 initially presented in D'Souza *et al*. (2006)
- However, direct impact accretion in DWDs is, in general, a radiative hydrodynamics problem so these results do not tell the entire story



Acknowledgments

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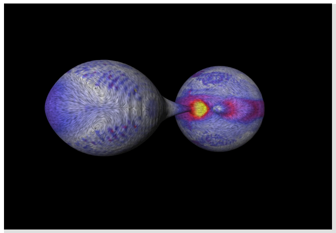
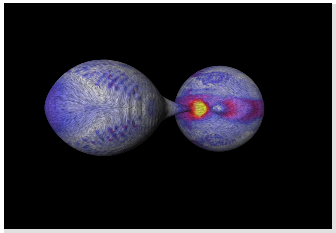
We are very grateful to Werner Benger and the Laboratory for Creative Arts and Technology at LSU for their help with visualizing our simulation data.





The Full Picture

$$\frac{\dot{a}}{2a} = -\frac{\dot{J}_A}{J_{orb}} - \frac{\dot{J}_D}{J_{orb}} - \frac{\dot{M}_D}{M_D}(1-q)$$